Understanding Technological Culture through a Constructivist View of Science, Technology, and Society.

2

Understanding Technological Culture through a Constructivist View of Science, Technology, and Society

WIEBE E. BIJKER

The term "social constructivism" has come to characterize much current thinking within the STS field. One of the chief proponents of this view has been Wiebe Bijker, professor of technology and society at the University of Maastricht in the Netherlands. Bijker first developed his constructivist line of thinking in a historical-sociological assessment of the development of the bicycle, which was published as part of a collection of essays he coedited with Trevor Pinch and Thomas Hughes, *The Social Construction of Technological Systems* (1987), a book that has since become a benchmark in the field. He is also the author of *Of Bicycles, Bakelites, and Bulbs: Toward a Theory of Sociotechnical Change* (1995).

In this chapter Bijker argues that because "we live in a technological culture," we have an obligation to try to *understand* [that] technological culture." At the same time he wants to *politicize* it—that is, "to make explicit the political dimensions of the role of science and technology, to question the self-evident character of technological culture, and to put science and technology on the public agenda for political deliberation." Finally, he hopes to *democratize* modern scientific and technological culture by engaging more citizens in such political deliberation.

Not only is the centrality of Bijker's view important to understanding STS as a field of study, but it is this very same constructivist view that helps to justify his and other activist arguments that citizens have both a democratic right and a responsibility to participate in the sociopolitical decision-making process so central to contemporary technological culture. In reading Bijker's essay, we should consider whether the constructivist view offers a clearer and more helpful understanding of science and technology than the view of science as objective and value free, or of technology as autonomous. We should also attempt to assess whether such a constructivist framework truly offers, as Bijker suggests, an opportunity for enhanced democratic participation in scientific-technical decision-making.

We Live in a Technological Culture

We live in a technological culture—in a culture that is thoroughly influenced by modern society and technology. It is thus not easily possible, I will argue, to understand modern Western culture without taking into account the role of science and technology. Indeed, this pertains to all aspects of this culture, not only to those that are openly linked to technology and science, such as communication, mobility, and environmental problems. Also other aspects of our culture are infused with science and technology—for example *language* (think of the common usage of metaphors derived from communication and computer technology); and *norms and values* (think of the differentiation of norms as to whether someone is "really" dead, as a result of the increased sophistication of organ transplant technologies); and *identity* (think of all the technological ways in which one's identity is defined: credit cards, health registrations, type of motorcar). It is to summarize this observation regarding the pervasiveness of science and technology in modern Western culture, that I use the sloganlike phrase "we live in a technological culture." It is not to argue that technology and science are the only important, or even the most important, aspects of our culture, but it is to argue that we cannot hope to understand modern culture without taking into account science and technology. It is, in other words, arguing for the pertinence of science-technology-society (STS) studies.

In this chapter I will introduce the constructivist perspective in STS studies. Besides briefly outlining the perspective itself, I will also address the wider issue of the future intellectual and political STS agenda, and the pertinence of a constructivist approach for such an agenda.

Understanding, Politicizing, and Democratizing Technological Culture

I want to argue that all who live in this culture—citizens, scientists, engineers, STS-students—have an obligation to try to *understand* the technological culture. This is basically the nineteenth-century enlightenment ideal. And, as argued above, we do need insight into the interplay of science and technology in society for such an understanding. My further goal, but not one which all will share, is to *politicize* technological culture: to make explicit the political dimensions of the role of science and technology, to question the self-evident character of technological culture, and to put science and technology on the public agenda for political deliberation. A possible third goal is to *democratize* technological culture: to promote particular normative choices of democracy when engaging in the debate on politicization. Even though there will be least agreement as to this last goal—people are likely to disagree about the particulars of their democratic ideals, as well as about the strategies to realize them—I will return to this issue in the conclusion. The main body of the essay is meant to provide a framework within which to understand technological culture, one with a specific sensitivity to its political aspects.

The Standard View of Science, Technology, and Society

Before presenting the constructivist framework, it is helpful to briefly discuss its counterpart, the standard image of science and technology—an image still widely held by citizens, students, and practitioners. In the standard image of science, scientific knowledge is objective, value-free, and discovered by specialists. Technology, similarly, is a rather autonomous force in society, and technology's working is an intrinsic property of the technical machines and processes. The left column of Table 2.1 summarizes this.

Some of the implications of these standard images are positive and comforting. Thus, for example, scientific knowledge appears as a prominent candidate for solving all kinds of problems. In the domain of political thought, this naturally leads to "technocracy"-like proposals, where technology is viewed as a sufficient end in itself and where the values of efficiency, power, and rationality are valued independent of context. The standard view accepts that

Table 2.1
Standard and Constructivist Images of Science and Technology

Standard *View of Science and Technology (and Society)*	Constructivist *View of Science and Technology (and Society)*
Clear distinctions between the political and the scientific/technical domain	Both domains are intertwined; what is defined as a technical or as a political problem will depend on the particular context
Difference between "real science" and "trans-science"	All science is value-laden and may—again depending on the context—have implications for regulation and policy; thus there is no fundamental difference between "real science" and "trans-science," "mandated science," or "policy-relevant science"
Scientific knowledge is discovered by asking methodologically sound questions, which are answered unambiguously by nature	The stabilization of scientific knowledge is a social process
Social responsibility of scientists and technologists is a key issue	Development of science and technology is a social process rather than a chain of individual decisions; political and ethical issues related to science therefore cannot be reduced to the question of social responsibility of scientists and technologists
Technology develops linearly, e.g., conception → decision → operation	Technology development cannot be conceptualized as a process with separate stages, let alone a linear one

(continued on next page)

technology can be applied negatively, but in this view the users are to be blamed, not the technology. Not surprisingly, the standard image also leaves us with some problems. For some questions, for example, we do not yet have the right scientific knowledge. Also an adequate application of knowledge is, in this view, a separate problem. The role of experts is problematic in a specific way: How can experts be recognized by nonexperts?; How can nonexperts trust

Table 2.1 *(continued)*

Standard *View of Science and Technology (and Society)*	Constructivist *View of Science and Technology (and Society)*
Distinction between technology's development and its effects	The social construction of technology is a process that also continues into what is commonly called its "diffusion stage"; the (social, economic, ecological, cultural . . .) effects of technology are thus part of the construction process and typically have direct vice versa implications for technology's shaping
Clear distinction between technology development and control	Technology does not have the context-independent status that is necessary to hope for a separation of its development and control; its social construction and the (political, democratic) control are part of the same process
Clear distinction between technology stimulation and regulation	Stimulation and regulation may be distinguishable goals, but need not necessarily be implemented separately
Technology determines society, not the other way around	Social shaping of technology and technical building of society are two sides of the same coin
Social needs as well as social and environmental costs can be established unambiguously	Needs and costs of various kinds are also socially constructed—depending on the context, they are different for different relevant social groups, varying with perspective

the mechanisms that are supposed to safeguard the quality of the experts?; And, finally, how can experts communicate that esoteric knowledge to nonexperts? In the realm of technology, an additional problem is that new technologies may create new problems (which, it is hoped, in due time will be solved by still newer technologies).

Acceptable solutions for solving these problems are well known, up to the point of being trivial: more scientific and technological research, peer review, scientific expert advisory committees, and technology assessment. It is equally clear, however, that these "solutions" do not lead to as complete a disappearance of problems as the standard image of technology suggests. In the next section I will present an alternative image of science and technology, one which will yield some implications for understanding and politicizing technological culture.

A Constructivist View of Science, Technology, and Society

In the 1970s and 1980s detailed empirical research on the practices of scientists and engineers led to the formulation of a constructivist perspective on science and technology. This work by sociologists, historians, and philosophers became known under the banners of "sociology of scientific knowledge" (SSK) and "social construction of technology" (SCOT). I will briefly introduce both.

The Sociology of Scientific Knowledge (SSK)

Scientific facts are not found, literally dis-covered, in nature, but they are actively construed by scientists.[1] Readings from instruments do not speak for themselves but need to be constructed into scientific facts by researchers. The processes in which this is accomplished are social by their very nature: human researchers interacting with each other. They cannot be understood as mechanically following methodological rules; if that were so, we could replace scientists by computers.

The key idea is that nature does not dictate scientific facts. The image of scientific research—that doing an experiment is asking a question upon which nature unambiguously shouts yes or no—is false. SSK-researchers can show the *interpretive flexibility* of observations and propositions: that other readings are possible. Which of the possible readings subsequently stabilizes into generally accepted knowledge is subject to social processes. That is not to say that scientific knowledge is irrational, or disorderly, or unrelated to scientific experiments. It is to say that in order to understand the outcome of scientific research, and especially scientific controversies, we should aim at finding regularities of a sociological nature.

SSK-research has produced a variety of such insights. The *experimenters' regress* is one such example (Collins, 1985). Think of an experiment to investigate gravitational radiation—a kind of radiation that is similar to light but produced by moving massive bodies rather than by moving electrons. (The existence of gravitational radiation is predicted by Einstein's general theory of relativity.) Suppose a controversy develops over the outcome of this experiment, for example, that gravitational waves do indeed exist and have a particular character. How do we resolve that controversy? By doing another experiment to test the first experiment! But then a controversy over that second experiment may develop, and so on ad infinitum. Collins coined this circular trap the "experimenters' regress." Experimental work can only be used to test something if a way is found to break out of this circle, for example, by having consensus about the existence of gravitational waves of a particular character on theoretical grounds.

The *splitting-and-inversion model* is another example of SSK insight (Latour and Woolgar, 1979). On the basis of their anthropological study in a California biochemistry laboratory, Latour and Woolgar conclude that the process of scientific discovery is one of splitting-and-inversion. During the process of "science in the making,"[2] there is no distinction between an object and the statement *about* that object—there merely is the statement. But at the moment of social closure, when scientific consensus is reached, *splitting* between the object and the statement occurs, and the scientific fact becomes a statement *about* some part of nature. Also at that moment *inversion* occurs: the arrows of time and causality are inverted and the object is seen as being previous to and, indeed, the source of the statement.

A third insight relates to the *political dimensions of scientific controversies*. If, for example, scientists argue about the safety of nuclear reactors, the standard image of science can only suggest that one of the conflicting parties is wrong and the others are the good guys—for scientific knowledge is, in this view, unambiguously dictated by nature, so what is there to argue about? In a constructivist view, controversy among scientists is quite normal. Science cannot deliver complete certainty. The standard view that science can deliver certainty entails, what Collins and Pinch call, "flip-flop thinking"—it is all good or all bad. They conclude:

> The trouble is that both states of the flip-flop are to be feared. The overweening claims to authority of many scientists and technologists are offensive and unjustified but the likely reaction, born of failed promises, might precipitate a still worse anti-scientific movement. Scientists should promise less; they might then be better able to keep their promises. Let us admire them as craftspersons: the foremost experts in the ways of the natural world (Collins and Pinch, 1993, p. 142).

The Social Construction of Technology (SCOT)

Since the 1980s, and building on the SSK work discussed above, sociological and historical stories have developed a constructivist analysis of technology in contrast to the standard image of technology that was largely "technological determinist." Social shaping models stress that technology does not follow its own momentum nor a rational goal-directed problem-solving path but is instead shaped by social factors. (See Table 2.1 for a summary of standard and constructivist images of science and technology.)

In the *social construction of technology approach* (SCOT),[3] relevant social groups are the starting point. Technical artifacts are described through the eyes of the members of these groups. The interactions within and among relevant social groups can give different meanings to the same. Thus, for example, a nuclear reactor may exemplify to a group of union leaders an almost perfectly safe working environment with very little chance of on-the-job accidents compared to urban building sites or harbors. To a group of international relations analysts, the reactor may, however, represent a threat through enhancing the possibilities of nuclear proliferation, while for the neighboring village the chances for radioactive emissions and the (indirect) employment effects may strive for prominence. As a workplace, nuclear technology is succeeding quite well; whereas, as a source for international tension or as an environmental hazard, it may be evaluated quite differently. This demonstration of *interpretive flexibility* is a crucial step in arguing for the feasibility of any sociology of technology—it shows that neither an artifact's identity, nor its technical "success" or "failure," are intrinsic properties of the artifact but subject to social variables.

The next step is to describe how artifacts are, indeed, socially constructed, thus tracing the increasing (or sometimes decreasing) degrees of stability of that artifact. The concept of "technological frame" is proposed to explain the development of heterogeneous socio-technical ensembles, thus avoiding social reductionism.

A technological frame structures the interactions between the "actors" of a relevant social group. A key characteristic of the concept is that it is applicable to all within the relevant groups—technicians and others alike.[4] It is built up when interaction "around" a technology starts and continues. Existing practice does guide future practice, though not completely deterministically. The concept of "technological frame" forms a hinge in the analysis of socio-technical ensembles: it sets the way in which technology influences interaction and thus shapes specific cultures, but it also explains how a new technology is constructed by a combination of enabling and constraining interactions within relevant social groups in a specific way.

The Politicization of Technological Culture

The constructivist conception of technology is, I want to argue, crucial for a discussion of the politicization of technology. The argument involves two steps. First, I will argue that a constructivist analysis, in some form, is a condition sine qua non for any politics of technology. This results in stressing the malleability of technology, the possibility for choice, the basic insight that things could have been otherwise. But technology is not only malleable and changeable—it can be obdurate, hard, and very fixed too. The second step, then, would be to analyze this obduracy of sociotechnical ensembles.

The constructivist perspective provides a rationale for a politics of technology. It does so by exemplifying the very possibility of a social analysis of technology. Demonstrating the interpretive flexibility of an artifact makes clear that the stabilization of an artifact is a social process, and hence subject to choices, interests, and value judgments—in short, to politics. Without recognizing the interpretive flexibility of technology, one is bound to accept a technologically determinist view. A technological determinist view does not stimulate citizens' participation in processes of democratic control of technology, since it conveys an image of autonomy and the impossibility of intervention.

Apart from having a role in the public debate about sociotechnical choices, to demonstrate the interpretive flexibility of sociotechnical ensembles is also crucial in a more analytical sense. For without such a perspective an analysis of technology and society is bound to reproduce the stabilized meanings of technical artifacts and will miss many opportunities for intervention. The interpretive flexibility of technology often will not be obvious and needs to be demonstrated in a rigorous way to escape the rather trivial level of observation that technology is humanmade, and hence subject to many societal influences. The constructivist argument is that the core of technology—that which constitutes its working—is socially constructed. This is a way to take up the challenge of Langdon Winner's observation that "artifacts have politics." Such a perspective seems necessary to overcome the standard view of technology and society, in which "blaming the hardware appears even more foolish than blaming the victims when it comes to judging conditions of public life" (Winner, 1986:20).

The Hardness of Facts and Machines

Let me now turn to the second step in the argument. To argue for the malleability of technology does not imply that we forget the solidity and momentum of sociotechnical ensembles. Such negligence might result in an equally counterproductive cultural-political climate, because it invokes too optimistic an expectation which in turn may cause disillusions. A politics and a theory of sociotechnology have to meet similar requirements here—a balance between actor and structural perspectives in the second. Sociotechnical ensembles not only have interpretive flexibility, they can also be fixed and obdurate, and they will accordingly function in the societal power struggles over technology.

We can distinguish two aspects of power—a *micropolitics of power*, in which technologies may be used as instruments to build up networks of influence, and a *semiotic power structure*, which results from these micropolitics and constrains actors (Bijker, 1995, chapters 4–5). The semiotic power originates from the fixity of meanings, which is built up during the formation of a technological frame as a result of the micropolitics of relevant social groups. The groups have, in building up the technological frame, invested so much into the key technology that this technology's meaning becomes fixed—it cannot be changed easily, and it forms part of an enduring network of practices, theories, and social institutions.

From this time on, it may indeed happen that, naively speaking, the technology "determines" social development. Such an "exemplary" sociotechnical ensemble is, at the same time, the result of micropolitical interaction processes and one of the elements of a semiotic power structure. A sociotechnical ensemble can also be an important boundary-creating instrument. Then it functions on the border between two relevant social groups, often especially in the hands of actors with a low inclusion in the respective technological frames.[5]

For the low included actors, such an artifact presents a "take it or leave it" choice—they have no chance of modifying the artifact when they "take" it, but life can go on quite well when they "leave" it. For the high included actors, on the contrary, there is no life without the exemplary artifact, but there is a lot of life within it. The obduracy of artifacts as boundary objects for low included actors consists in this "take it or leave it" character. For such actors, there is no flexibility; there is no differentiated insight; there is only technology, determining life to some extent and allowing at best an "all or nothing" choice. This is the obduracy of technology which most people know best. This is the kind of obduracy that gives rise to technological determinism. For high included actors, obduracy of technological ensembles presents itself as the technology being all-pervasive, beyond questioning, and dominating thoughts and interactions.

Artifacts as boundary objects result in obduracy because they link different relevant social groups together into a semiotic power structure. To make the "take it" choice with respect to such an artifact results in being included into such a semiotic power structure. This implies being subject to power relations that one would otherwise—in the case of a "leave it" choice—be immune to. Someone who buys a car, for example, is thereby included in the semiotic structure of automobiling: cars-roads-rules-jams-gasoline-prices-taxes. This will result in automobilists exerting power, for example by using the car during rush hour and thereby contributing to a traffic jam, but will also make them subject to the exertion of power by others—the traffic jam again. Without a car, however, jams and oil prices simply do not matter. "Exemplars," or key artifacts result in obduracy because they constitute to an important degree the world in which one is living. This also implies inclusion in a semiotic power structure but with different possibilities and effects. Many of the power interactions are now in terms of the exemplary artifact. Leaving the car standing is less likely an option, but changing one's driving hours or routes (to beat the jams), changing from gasoline to diesel or liquid gas (to beat the taxes), or changing to a smaller car (to reduce parking problems) are possibilities.

Different Kinds of Expertise

The issue of expertise lies at the heart of both the practice of doing STS and of a politicization of technological culture. Is the consequence of a constructivist view of scientific knowledge and technological devices—the view that the development of science and technology is a social process—that scientific expertise does not exist, or is irrelevant? This is not the case, neither for STS students, nor for participants in political debates about science and technology. I shall discuss both aspects in turn.

The expertise of any researcher, be it a physicist, a sociologist, or a philosopher, is formed and checked in a socialization process within the relevant scientific community. Key concepts to understanding this process are "peer review" and Kuhn's "paradigm" (1962). There is nothing different in the case of STS scholars. They too will acquire their expertise in undergraduate and postgraduate studies, being slowly socialized into the STS community. There is one difference, however, in contrast to other scientific disciplines. STS students study other sciences and engineering practices, which requires them to have a more than superficial knowledge of this other scientific or engineering discipline. As part of their research, STS researchers thus must also socialize a little into their object of study—that other community. This may seem rather self-evident, and no different from requiring an anthropologist who studies the culture of drug addicts to socialize into the drug scene, but in the field of STS this argument needs to be made explicitly. Until constructivist studies started in the 1970s, the view was generally held that science as an object of study was different from all other objects of study (such as the drug scene): the development of the *content* of science, of scientific knowledge per se, was not amenable to analysis by anyone other than the practicing scientists themselves. This is like arguing that the culture of the drug addicts can only be studied by the drug addicts themselves.

SSK changed this—the constructivists showed (as presented above) that the development of scientific knowledge is a social process and thus open to analysis by sociologists. The implication is, of course, that students need to familiarize themselves thoroughly with the culture that is the object of their study. In other words, the STS student must be prepared to acquire detailed scientific and technical knowledge, just as the anthropologist must be prepared to acquire such knowledge about the practices of drug dealing and use.

The reason for an STS student to acquire detailed scientific and technical knowledge that I just discussed is a methodological one—only on the basis of such knowledge can proper STS research thrive. There is as well, however, an additional, more political reason to stress this need. Without such detailed knowledge, STS scholars cannot claim any special authority to engage in discussions about the societal role of science and technology, and about the politics and policy of science and technology. This brings me to the second question of expertise—expertise in relation to the politicization of technological culture.

What about the expertise needed by other relevant social groups to engage in political debates about science and technology? Two arguments are relevant, and they define both extremes of a spectrum of answers to this question. The first argument is based on the standard image of science and technology. It runs as follows: science and technology are special domains, and the expertise of scientists and engineers is needed to discuss its development. There is a clear distinction, however, between the contents of science and technology and their applications. About these applications other social groups of citizens and politicians can debate.

The second argument is based on a naive and extreme form of social constructivism and runs as follows: science and technology are in no way different from other domains, and there is no reason to give the expertise of scientists and engineers any special status. I think this latter argument is as foolish as the first. The constructivist perspective of science and technology, the one that I have presented in this essay, does not support the view that scientific expertise is nonexistent, or irrelevant, or identical to the expertise of any nonscientist.

I want to conclude that a constructivist view of knowledge and technology implies the existence of *a variety of expertise*. Different relevant social groups have their specific kinds of expertise—we are all experts in specific ways. Note the "specificity" condition: scientists have their own invaluable form of expertise, as do STS scholars, and also groups of citizens, politicians, and other experts. I am not arguing that an average citizen is able to design a nuclear reactor or a river dike, but I am arguing that more is involved in designing large projects such as nuclear power stations and water management systems than is described in the engineers' handbooks. For those aspects, others are experts and need to be involved, and they need to be involved *in the whole design process* in as early a stage as possible.

Conclusion: Learning Programs for Citizens, Scientists, and STS Students

Let me, by way of conclusion, briefly turn to the issue of democratization of technological culture. First of all, it is important to recognize that the concept of democracy can have different meanings in different cultures—for example, the Jeffersonian ideal of direct democracy is quite different from the representational elitist European ideal of democracy, a distinction that will yield very different proposals for a democratization of technological culture.[6] Transcending these differences, I think that it is possible to sketch some of the consequences of the view that I have presented in this essay as to the way in which various groups should relate to the issue of democratizing technological culture.

For citizens the consequence is that more educational time should be spent on scientific and technical literacy, in combination with STS teaching. The first, without the latter, is only useful for future scientists, not for future citizens. It also means that citizens can and should be informed about and involved in discussions about scientific and technological developments, although the precise form will depend on the model of democracy that one supports. In such a technological culture, scientists and engineers are expected to engage with other social groups about their work. This implies that also they should be taught STS insights to enable them to reflect upon their work and its implications for society. STS students themselves should continue to engage in science and engineering practices, partly as a prerequisite for their research and partly as a contribution to developing a politicization of technological culture.

Notes

1. See Collins and Pinch (1998b) and Collins and Pinch (1998a) for a good first-level introduction to SSK. See Collins and Latour (1987) for more sophisticated discussions of various constructivist views of science.

2. This phrase is coined in Latour (1987).

3. See Bijker (1995) for a full account of this social construction of technology approach.

4. It is on this point that "technological frame" differs crucially from concepts such as Kuhn's (1962) "paradigm" or Dosi's (1982) "technological paradigm."

5. An actor's inclusion in a technological frame determines the degree to which this frame guides the thinking and interacting of the actor. A high included actor works and thinks very much in terms of the technological frame; an actor with a low inclusion much less so.

6. See Wilde (1997) for a critique of the naivety of STS scholars in this respect.

References

Bijker, Wiebe E. 1995. *Of Bicycles, Bakelites and Bulbs: Toward a Theory of Sociotechnical Change, Inside Technology*. Cambridge, MA: MIT Press.

Bijker, Wiebe E., Hughes, Thomas P., and Pinch, Trevor, eds. 1987. *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology*. Cambridge, MA: MIT Press.

Collins, Harry. 1985. *Changing Order: Replication and Induction in Scientific Practice*. London: Sage.

Collins, Harry, and Pinch, Trevor. 1993. *The Golem: What Everyone Should Know About Science*. Cambridge: Cambridge University Press.

———. 1998a. *The Golem: What You Should Know About Science*. 2nd ed. Cambridge: Cambridge University Press.

———. 1998b. *The Golem at Large: What You Should Know About Technology*. Cambridge: Cambridge University Press.

Dosi, Giovanni. 1982. "Technological Paradigms and Technological Trajectories: A Suggested Interpretation of the Determinants and Directions of Technical Change." *Research Policy*, vol. 11, no. 3, pp. 147–62.

Kuhn, Thomas. 1962. *The Structure of Scientific Revolutions*. Chicago: University of Chicago Press.

Latour, Bruno. 1987. *Science in Action: How to Follow Scientists and Engineers Through Society*. Cambridge, MA: Harvard University Press.

Latour, Bruno, and Woolgar, Steve. 1979. *Laboratory Life: The Social Construction of Scientific Facts*. Beverly Hills, CA: Sage.

Wilde, Rein de. 1997. "Sublime Features: Reflections on the Modern Faith in the Compatibility of Community, Democracy, and Technology." Pp. 29–49 in Sissel Myklebust, ed., *Technology and Democracy: Obstacles to Democratization—Productivism and Technocracy*. Oslo: TMV, University of Oslo.

Winner, Langdon. 1986. *The Whale and the Reactor: A Search for Limits in an Age of High Technology*. Chicago: University of Chicago Press.